Quo Vadimus – Future Prospects for the Earth’s Population
Comments on the worldwide situation concerning available energy and food sources, the consequences of climatic change, and available water resources

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Quo Vadimus –Future Prospects for the Earth's Population
Comments on the worldwide situation concerning available energy and food sources, the consequences of climatic change, and available water resources

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The problems of our earthly future have already been critically examined in the years 1972 and 1974 in reports to the "Club of Rome" by D. MEADOWS in "The Limits of Growth" and by Eduard PESTEL and M. MESAROVIC in "Mankind at the Turning Point", and prognoses were given for the coming century [1,2]. Nothing concerning those alarming results has changed substantially from then up to the present day. The frightening increase in the population of our earth, our limited energy and food sources, the climatic changes with all their resultant symptoms, the limited availability of water and increasing environmental pollution still remain the problems and dangers with which science and international politics must come to terms. This will be the case to an even greater extent in the future.

1. Population Increase

The population of the earth in 1997 comes to about 5.8 billion – that is 5,800 million people (Fig. 1). Despite all the governmental control measures aimed at providing information, the yearly growth rate is still about 2 %. This means that the population of the earth in 1990 increased by about 300,000 people per day (!) or 12,500 people per hour or about 200 people per second (Fig. 2). Using these numbers as a basis, this means that the earth's population will double in about 30 years, i.e. by the year 2030 about 11.0 billion people will populate our globe (Fig. 2).

This predicted enormous population increase, which primarily will be found in the east Asiatic countries (China, Indonesia, India etc.) has already brought scientists and politicians from all countries of the world onto the scene because, according to rough estimates, the supply of the earth's food and energy will not be sufficient for a population of that size.

2. Energy Reserves and Energy Needs

In 1990, the energy consumption our earth amounted to about 11.2 billion t SKE, where 1 billion t SKE = 29.3 x 10^{12}MJ. Of that, about 27.4 % came from coal reserves, about 40 % from oil reserves, 23 % from natural gas, 2.3 % from water power, and 7.3 % from nuclear power [3,4]. In a study compiled worldwide the available energy reserves in 1990 were estimated at about 1,370 billion t SKE, using present methods of energy production (Table 1).

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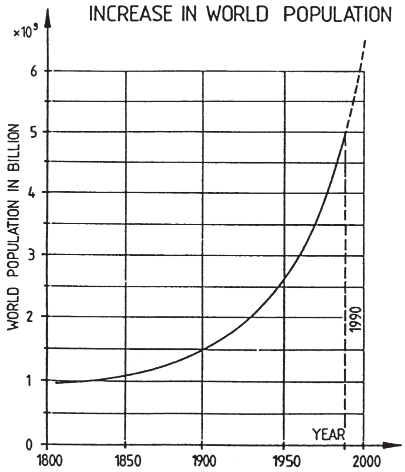

Fig. 1: Increease in World Population

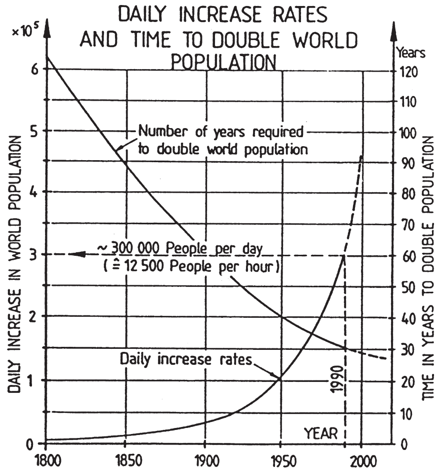

Fig. 2: Daily Increase Rates in the World Population

Table 1: Worldwide Available Energy Reserves (1990) in Billion t SKE

	Coal	Oil	Natural Gas	Uranium	Total
North America	231,1	13,6	9,6	42,7	297,0
Middle and South America	6,1	24,5	7,6	7,8	46,2
Western Europe	91,3	5,9	7,2	7,4	111,8
Middle East	220,0	15,7	49,8	112,1	397,6
Africa	58,4			29,9	
China	100,5	3,6	1,0	39,0	144,1
Far East	27,4	3,3	6,8	3,1	40,6
Australia	40,1	0,3	0,8	23,9	65,1
Total Reserves in Bell. t SKE	782,3	192,7	127,6	266,1	1.367,7

The percentage distribution of the individual energy sources up to the year 2010 (estimated) are shown in Figure 3 [6].

If you assume a quite realistic yearly growth rate of global energy requirements at about 2 %, then the currently available energy reserves would be used up by about the year 2050 (Fig. 4). This is assuming, however, that by 2050 no additional energy reserves are developed or made utilizable. Worldwide estimates have nevertheless indicated additionally obtainable energy supplies of about 870 billion t SKE which, if completely developed, could cover worldwide energy requirements approximately to the year 2070 [4,5].

The availability of the primary energy supplies in the world varies. Taking conventional extraction methods as a basis, the existing coal deposits would last for about another 250

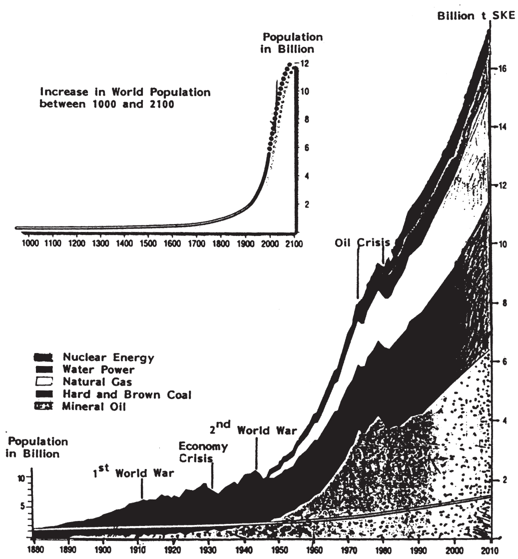

Fig. 3: Percentage Distribution of the Individual Energy Sources in the World Energy Consumption

Table 2: Primary Energy Consumption in Germany (in Billion t SKE) [7]

Energy Source	1995	1998	2001
Mineral Oil	164,1	197,1	190,3
Hard Coal	95,5	103,0	106,6
Brown Coal	70,3	70,3	65,0
Nuclear Energy	57,4	60,2	63,7
Water Power	2,6	2,2	2,4
Wind Energy	0,2	0,5	1,4
Other Sources	7,6	140,5	9,8
Totel in Bill. t. SKE	486,9	495,5	494,8

years, the petroleum reserves for about another 45 years, the supply of natural gas for about 60 more years and the uranium reserves for about another 55 years if used without reprocessing. With its use on a light water reactor, through recycling, however, the range of uranium can be increased by up to 60 times its amount [5].

In the Federal Republic of Germany the primary energy consumption in 1995 was about 486 billion t SKE, in 2001 it augmented to 495 billion t SKE. Table 2 shows the energy consumption according to energy sources [7].

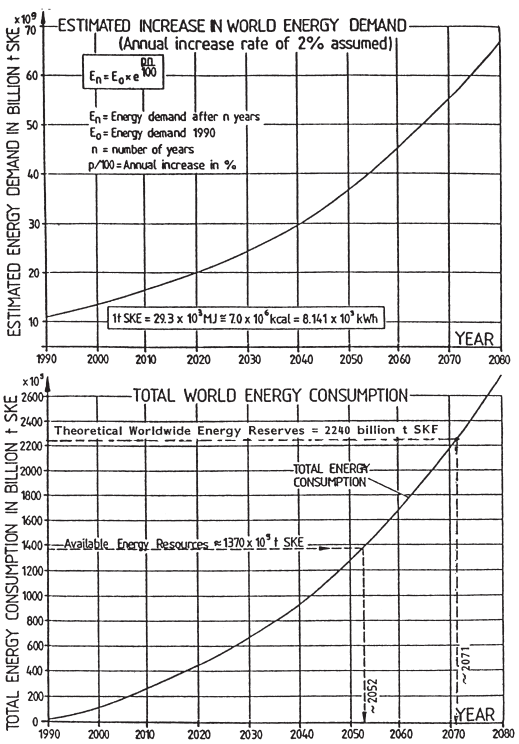

Fig. 4: Increase in the World Energy Consumption and Available Energy Reserves

3. Alternative Energy Sources

The limited energy reserves worldwide require as our urgent responsibility the tapping of new energy sources and the development of corresponding technologies for economic utilization. These include the development of geothermic and biochemical energy, wind and solar energy as well as the use of wave and tidal energy.

In view of the risks which are connected with the production of energy from nuclear power plants, especially with the as yet unsolved question of the permanent disposal of nuclear waste, and because of the limited supplies of coal, oil, and natural gas, only the utilization of the previously mentioned alternative energy sources remains. Whereas the energy development from wind, wave, and solar sources is to a large extent limited to local conditions, through the exploitation of the earth's heat and the utilization of tidal energy a not inconsiderable share of future energy needs could be satisfied.

Herein lies one of the great tasks for scientists and engineers in the development of new processes and economically tenable designs for the use of these energy sources available worldwide.

Fig. 5: Installed Onshore Wind Turbines at the North-Sea Coast
of Schleswig-Holstein/Germany [25]

With respect to the renewable energy sources such as wind, wave and tidal energy, solar and geothermic energy, the European Union plans for the year 2010 an increase of up to 22 % of the total energy consumption of the European countries involved.

This aim can be reached, in particular, by the utilisation of wind power. The development and increased installation of wind turbine units in Denmark, Holland and Germany has been remarkable in the past few years. In the year 2000, the installed capacity in Germany was already more than 6,000 MW, compared, for example, with the installed capacity in the United States of only 2,500 MW [22] (Fig. 5).

The newest trend in the use of wind energy is the construction of offshore wind power units. In Denmark an installed capacity of up to 4,000 MW of offshore installations is planned for the year 2030, whereas in Germany a total of 13 wind parks, each with a final capacity of 1,000 MW, is planned in the North Sea and in the Baltic Sea in water depths up to 40 m. This project is currently under discussion, and extensive investigations are currently being carried out on the possible effect of these large offshore installations on the ecology and the habitat of fauna and flora of the surrounding sea area [23].

The economic feasibility of these offshore installations depends to a high degree on the probability of the wind power to be expected. For their construction design the wave climate, the tidal currents and the sea-ground conditions are decisive. Figure 6 shows different concepts for the foundation of offshore wind turbines.

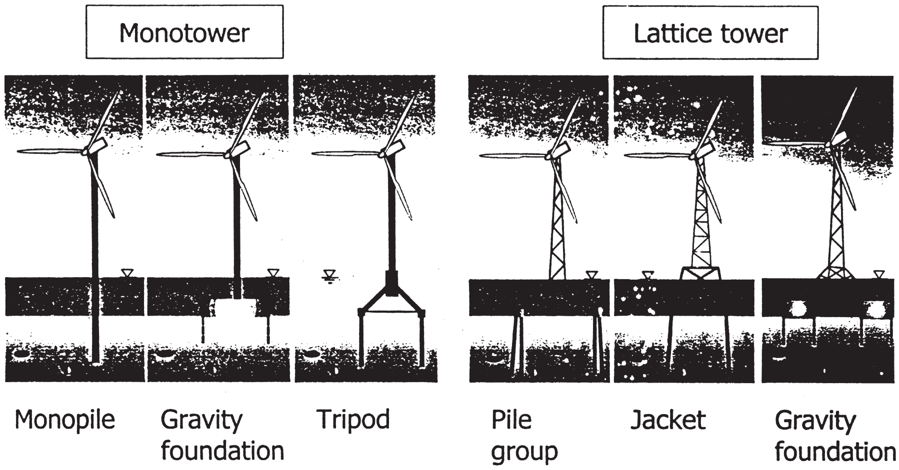

Fig. 6: Foundation Concepts for Offshore Wind Turbines

Up to now there has been only one tidal power plant in St. Malo, France, with an installed capacity of 240 MW, i.e. with about 1/5 of the capability of a modern nuclear power plant (Fig. 7). A study undertaken worldwide showed, however, that there are more than 100 other suitable sites on earth for the establishment of a tidal power plant, a series of which has already been more closely examined with regard to possible energy production in Australia, India , Brazil, England, Germany, France, Korea, China, USA, Canada, Argentina, and the former Soviet Union. Globally the possible economically justifiable utilization of tidal energy is estimated at about 200,000 MW. This approximately corresponds to the productivity level of about 150 nuclear power plants each with 1,300 MW of established power output [8].

4. Warming of the Earth's Atmosphere

The heat balance and the surface temperature of the earth are strongly influenced by the presence of water vapor, carbon dioxide and other trace gases in the atmosphere. When the sun's radiation hits the earth's atmosphere a part of it is reflected back into space or absorbed into the atmosphere. About 50 % of the sun's radiation reaches the surface of the earth and is converted there into UV-radiation or heat. The heat radiation is then absorbed by the layer of clouds or by water vapor, carbon dioxide and other trace gases, through which it is again returned to the stratosphere (Fig. 8).

As a result of the continuous increase in the world population and its resultant rising energy consumption, an increase in CO^2 and other trace gas production will occur through the burning of coal, oil, and natural gas. Through these gases heat is absorbed to a greater extent and reflected back to the earth. This leads to a gradual warming of our earth's atmosphere and is known as the "greenhouse effect".

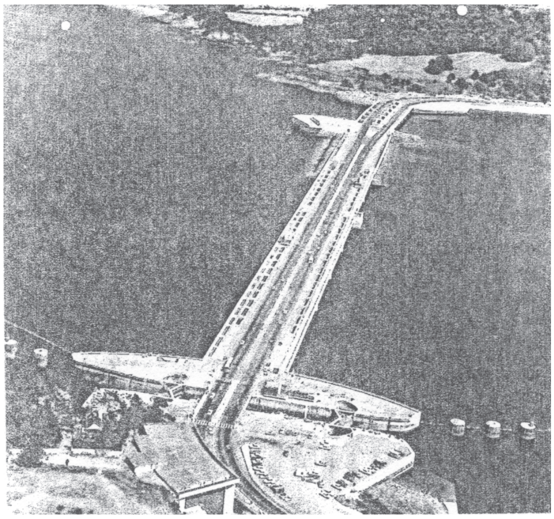

Fig 7: Tidal Power Plant in St.Malo/France (Installed Capacity = 240 MW)

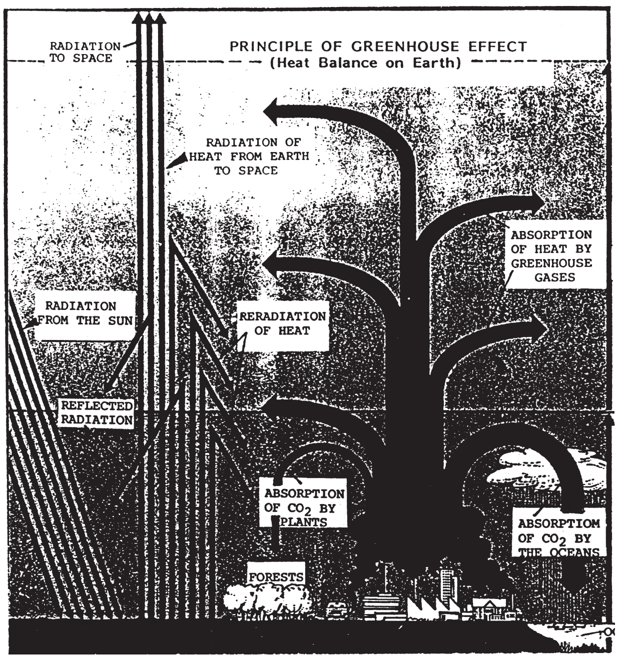

Fig. 8: Principle of Greenhouse Effect

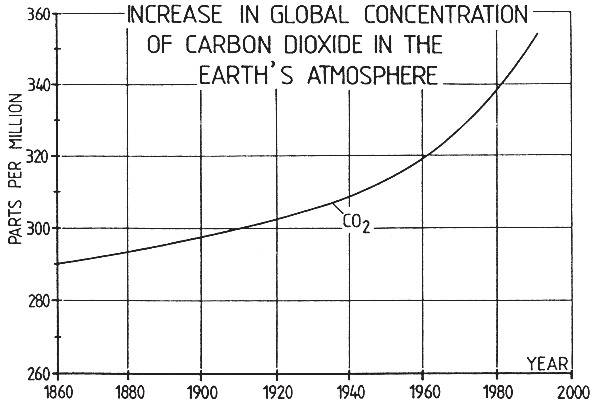

Fig. 9: Increase in the Concentration of Carbon Dioxide in the Earth Atmosphere

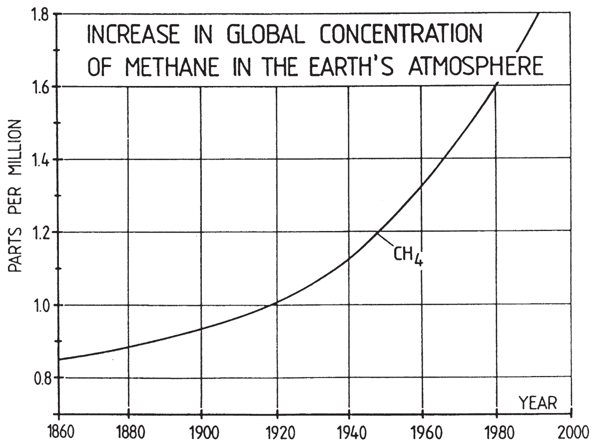

Fig. 10: Increase in the Concentration of Methane in the Earth Atmosphere

A substantial percentage of heat and CO^2 gases is absorbed by the oceans and the earth's vegetation, and especially by the tropical rain forests which cover 12 % of the earth's surface (17.5 x 10^6 km²). Through photosynthesis plants absorb CO² gases and store carbon monoxide.

The constant clearing of rain forests (yearly an area of about 560.,000 km²) for economic reasons and for the purpose of feeding and housing the growing population without a doubt contributes to a disturbance of the balance of heat on earth and leads to a further warming of the earth's atmosphere.

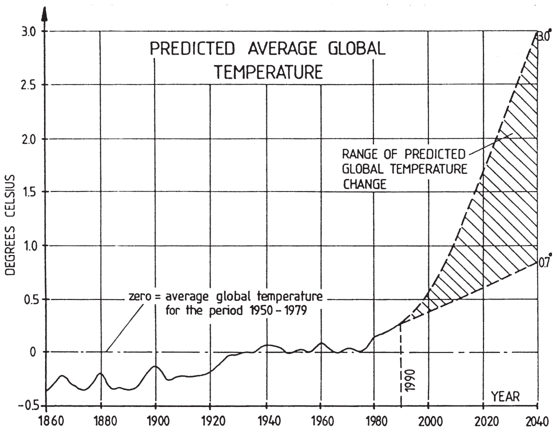

Fig. 11: Increase in the Temperature of the Earth Surface

The cause of the increasing production of greenhouse gases is to be found mainly in the constantly increasing population of the earth, but also in progressive industrial development and in economic growth. The burning of fossil fuels generates carbon dioxide, the fertilizing of agricultural fields releases NO^2, and rice production, livestock farming, and the clearing of forests produces methane gas.

More exact measurements and examinations show a constant increase in the concentration of carbon dioxide (CO^2), methane (CH^4), and other trace gases in the earth's atmosphere (Figs. 9 and 10). Calculations of the US National Academy of Sciences showed that with a doubling of the atmospheric CO^2 concentration and a corresponding increase in the concentration of other trace gases the mean temperature of the earth would rise by about 1.5 degrees to 4.5 degrees C [9,10]. In different mathematical climatic models the attempt was made to calculate the expected increase in 30 to 50 years of the mean temperature of the earth's surface and to estimate the resultant consequences for the climate, the weather, evaporation and precipitation, for agriculture and forestry as well as for the melting of the polar icecaps. Corresponding to assumptions about the possible reduction in greenhouse gas emissions, different values result for the increase in temperature of the earth's mean surface temperature. For the coming 50 years the values for the temperature increases are between 0.7 degrees and 3.0 degrees C (Fig. 11).

The predicted increase in the earth's mean temperature indicated among other things, great economic losses for the world and disadvantages for the world's population. These signify the great tasks for the engineers and scientists of the coming generation, but also great obligations on politically responsible governments to reduce the output of greenhouse gases to a minimum through suitable measures, as well as to end the further destruction of tropical rain forests. International monitoring programs are required here as well as close cross-border cooperation between the European countries which are especially affected.

5. Increase in the Mean Level of the Seas

In addition to the effect of climatic change of the earth on weather conditions, evaporation, precipitation and on agriculture, there is yet another effect which leads to very serious consequences for many inhabited coastal regions of the earth: the predicted rise in the mean seawater level.

Figure 12 shows the increase in the mean seawater level as far as it could be registered and calculated for the past 20,000 years. Analysis and evaluation of different tidal gauges over the past 150 years showed a gradual increase in the mean ocean level by between 10 cm and 25 cm over the last 100 years [13].

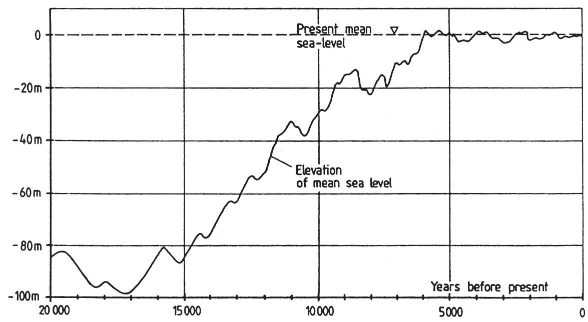

Fig. 12: Anticipated Increase in the mean Seawater Level during the last 20.000 years

Since about 1970, however, a rather strong increase in the water level has been observed worldwide. First figures resulted in the fact that, corresponding to local conditions which are the basis for the calculations, an increase in the oceans' water level of between 0.7 m and 2.0 m in the next 50 years must be anticipated (Fig. 13). The latest international research shows, however, that these values still require further discussion [19,20,21]. According to an IPCC-study (Intergovernmental Panel on Climate Change) of 1996, the increase in the oceans' water level in the next 100 years will be between 0.20 m and 0.96 m with a probable value of 0.55 m/100 years [18]. This would still be double the amount of the local increase observed up to now in the water level of the German North Sea coast of about 0.25 m/100 years.

In any case, this would have as a consequence a worldwide increase in the mean seawater level, which means that one must reckon with great floods and coastal erosion, the penetration of saltwater into rivers, bays, and sewage systems, great losses of usable agricultural lands as well as enormous investments for the converting of sea harbors, locks, and tidal barriers. Just an increase in the height of sea dikes of 1.0 m at the North Sea in Germany, Holland, Denmark, and Belgium would according to rough estimates already require, 5 to 8 billion Euros [14,15].

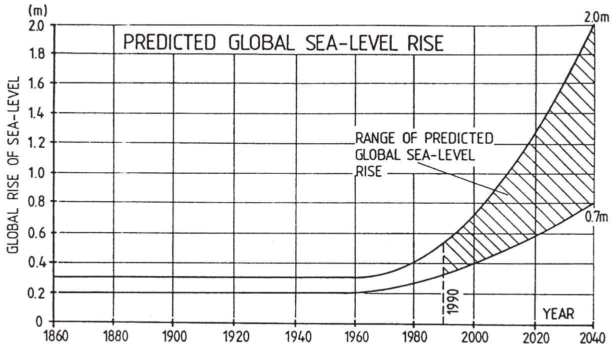

Fig. 13: Anticipated Increase in the mean Seawater Level in the next 50 years

6. Water Resources and Water Requirements

A further great problem for the coming decades will be the earth's limited water supply. 97 % of the world's total water supply consists of salty seawater which is not immediately usable for human consumption. After deducting the salty water of inland lakes, only 0.65 % of the entire supply remains as usable fresh water resources, of which, however, actually only about 25,000 billion m³, i.e. about 0.02 % of total water resources are usable [16].

The water requirement of its various consumers is in direct contrast to the available water supply. In 1975, water usage amounted to about 10 % of the availability, for the year 2000 a requirement of 24 % of the available reserves must be reckoned with. This share will rise correspondingly with the doubling of the earth's population in the year 2030. Despite that, the supply of fresh water would be numerically sufficient if the local availability and water quality were sufficient. The problem of water management is therefore not a problem of the quantity but a question of its management with regard to water quality control and the local and timely balancing of water beyond borders and continents [16,17].

Here again there is a long series of technical and scientific ways of looking at the problems which have to be solved in the coming decades. It is especially water quality control which must urgently order a halt to the increasing pollution as well as to warming and harmful chemical substances being dumped into our inland and coastal waters. Here the study and recognition of permissible maximum tolerable levels of pollution beyond all political borders and the monitoring of the degree of observance of the recommended guidelines of the responsible governments becomes a task of urgent priority for international committees.

7. Nutritional Needs and Food Supply

An especially conspicuous problem globally is that of the sufficient provision of food. Today 1/3 of the earth's population is already not sufficiently supplied with foodstuffs.

According to a more recent investigation there is worldwide about 3.2 billion hectares of agriculturally usable land, of which half is already being used. For the remainder, high investments for clearcutting, irrigation and fertilizing are necessary.

If one assumes the point of view that in order to feed every human being a minimal land requirement of 0.4 hectares per person is necessary. then it can easily be proven that even under the assumption that all arable land on the earth's surface were used, in the year 2000 a hopeless shortage of land must already arise. By doubling the productivity of land available for agriculture one would gain about 30 years, with an increase in productivity many times over about 60 years, until there is a nutritional economic crisis worldwide. It is, however, fairly certain that before that happens a district shortage of the required fresh water supply for irrigation will occur which will set limits for the optimisation of agricultural usage.

8. Conclusions

The series of indicated problems which will preoccupy humanity globally could be continued at will. Therefore it is high time that scientists from all professional disciplines intervene to a greater extent in the process of solving these problems. To this end it is also necessary that on the political side a national process of rethinking beyond all borders should take place, first in the European sphere and later at a global level. Supporting this important step is the ethical and scientific responsibility and obligation of all of us for the coming decades.

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Zum hier angesprochenen Problemkreis siehe auch den Beitrag von Dieter Kind auf Seite 93 ff. dieses Bandes.